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# Comparison of Screening Otoacoustic Emission Devices for Pre-school Aged Children

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An Independent Study submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Audiology

Department of Communication Sciences and Disorders

Illinois State University

May 2017

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# Comparison of Screening Otoacoustic Emission Devices for Pre-school Aged Children

## ABSTRACT

Hearing screenings for the pediatric population are intended to identify hearing losses that may otherwise go undetected. Otoacoustic Emissions (OAEs) are a screening tool that is quick, easy to administer, and requires little to no participation from the participant. A recent study in our lab has examined the impact of probe type and digital noise reduction on signal amplitude, noise floor amplitude, and test-retest reliability for Distortion Product Otoacoustic Emission (DPOAE) testing in young normal hearing adults. Signal-to-noise ratios were similar between the two devices. However, response amplitude, noise floor and test retest reliability were significantly different between devices. The device with a foam ear tip had greater response amplitude and better test-retest reliability compared to the device with a rubber probe tip. The device with the rubber-tip likely had similar SNRs due to digital noise reduction. The aim of the current study is to compare these results from young normal hearing adults with results from pre-school aged children. DPOAEs were measured twice in both ears under two conditions. One condition with the Natus AuDx (using foam probe tips without digital noise reduction) and one condition with the Etymotic (Maico) Eroscan Pro OAE screener (using rubber tips with digital noise reduction). Data from preschoolers does not support the findings for adults. DP amplitudes were greater across all frequencies with EROSCAN and test retest differences were high for both devices compared to the study with adults. Also, SNRs were better for preschoolers with EROSCAN, likely a result of greater response amplitude compared to AuDx. This likely relates to the smaller ear canal volume in preschools compared to adults, and the possibility of deeper probe-tip insertion with EROSCAN.

# INTRODUCTION

Undetected hearing loss in infants leads to speech, language, cognitive, and behavioral delays. Children identified with hearing loss before 6 months of age have better oral and aural language skills than those identified after 6 months of age. Because early identification is so important, the U.S. Preventative Services Task Force, the Recommended Uniform Screening Panel, and the Joint Committee on Infant Hearing have recommended hearing loss screening in all newborns (Nazir, 2006). Early Hearing Detection and Intervention (EHDI) programs are now established in all jurisdictions within the U.S. EHDI programs focus on newborn hearing screenings and follow-up. Follow-up is important because of the prevalence of late onset and acquired hearing loss. The goal of EHDI is for newborns to be screened by 1 month of age, an audiologic evaluation completed by 3 months of age for infants that fail the initial screening, and audiologic services provided by 6 months of age for infants that are deaf or hard of hearing. (Nierengarten, 2016).

The National Center for Hearing Assessment and Management (NCHAM) and the Center for Childhood Deafness at Boys Town National Research Hospital conducted a national survey of primary care physicians to assess their knowledge, skills and participation in EHDI. The survey was administered again in 2012-2013 to assess progress. Only 29% of the respondents did newborn hearing screenings and only 23% of those used objective measures. Most of the respondents did not report the results back to their EHDI coordinator. Because of this lack of participation, many children fall through the cracks of the EHDI system and are lost to follow-up. Along with loss to follow-up, hearing screenings for the pre-school aged population are important because of the prevalence of progressive hearing loss, late onset hearing loss, and acquired hearing loss from ototoxicity or infections like otitis media. While newborn hearing

screenings help reduce the age of identification, not all hearing loss is identified or even present at birth or during the newborn period. A study by Watkin and Baldwin in 2012 found that less than 60% of kindergarten-aged children with moderate or worse hearing loss had been identified during their newborn hearing screening (Prieve, 2015). Therefore, pre-school hearing screenings may catch hearing loss that was either undetected or not present during a newborn hearing screening.

There are numerous ways to screen infants' hearing. Common methods are automated brainstem response (ABR) testing and otoacoustic emissions (OAEs). OAEs are objective, quick and easy to administer, require little to no participation from the subject, and give a prediction of normal vs. abnormal hearing for each ear. OAEs test the integrity of the cochlea and are sensitive to middle ear abnormalities, such as infection, which are common in young children due to Eustachian tube anatomy. Distortion product OAEs (DPOAEs) are typically used because they predict normal vs. abnormal hearing across a large range of frequencies (1500-6000 Hz) and can detect mild high-frequency hearing loss and unilateral hearing loss. DPOAEs are the product of the nonlinear process of a normally functioning cochlea. A two-tone stimulus produces a third tone that differs from the stimuli. The most robust DPOAE occurs at 2f1-f2 where f1 is the lower frequency tone and f2 is the higher frequency tone. The f2/f1 ratio of 1.22 produces the largest 2f1-f2 distortion products.

OAEs are sensitive to ambient and physiologic noise. High noise levels, like in a daycare setting for example, subject artifact, and probe tube placement can affect the pass/fail outcome. The noise floor must be low and the OAE amplitude must exceed the noise floor by 6 decibels. The standard pass/fail criteria is a 6dB signal-to-noise ratio. Two commonly used OAE devices are the AuDx by Natus and EROSCAN Pro by Etymotic (Maico). Both devices are simple to

use, but they use different probe types and have different default protocols. The AuDx uses foam probe tips and does not have digital noise reduction. EROSCAN Pro has rubber probe tips and has digital noise reduction.

A recent study in our lab compared the pass/fail rate between the two devices in normal hearing young adults. DPOAEs were measured twice in quiet and twice in noise. There were no significant SNR differences between the two devices, but AuDx had higher DPOAE response amplitudes and Eroscan had lower noise floor amplitudes. SNRs were better in the low frequencies with EROSCAN because the device had a lower noise floor in the low frequencies. Consistent probe tube insertion with AuDx (foam) reduced test-retest variability.

The purpose of this study is to investigate the performance of two OAE screeners in a typical screening environment for a class of pre-school aged children. The research questions addressed here are whether there are systematic differences for results obtained with a device that uses rubber probe tips and digital noise reduction compared to a device using foam probe tips and no digital noise reduction. These comparisons include noise floor amplitude (NF), DPOAE amplitude (AMP) and test/retest repeatability (TRT).

# METHODS

## Participants

Fifty preschoolers in Metcalf Laboratory School were recruited to participate. Hearing sensitivity was assessed through pure tone testing and tympanometry. Data was collected for 11 students. 3 sets of data were incomplete and not included in the statistical analyses.

## DPOAE Devices

One AuDx Pro and one Eroscan Pro unit were provided on loan by the Communication Sciences and Disorders department at Illinois State University. No additional financial support or incentives were provided. Each of these devices was calibrated. Both devices were returned to the university at the conclusion of the study. Both devices were set to their default hearing screening protocol using 2000, 3000, 4000 and 5000 Hz center test frequencies with a L1/L2 presentation level of 65/55 dB SPL and F2/F1 frequency ratio of 1.22.

## Personnel

In order to stimulate real-world test results that would occur for a hearing screening such as for an early childhood daycare program, we utilized audiology graduate students who were knowledgeable of DPOAEs but relatively inexperienced in perform actual DPOAE testing.

## Protocol

Consent to participate in this study was obtained by each students' parent via a flyer that was sent home with each student. Only the students that gave consent were included in the study.

Screenings were performed during the regularly scheduled class time, so as not to disrupt the school day schedule. During their class, each participant was brought into a room adjacent to their classroom, one at a time. Otoscopy, a visual inspection of the eardrum and ear canal, was performed on each student in each ear. This was done with a Welch-Allyn rechargeable otoscope with disposable specula. Tympanometry was performed on each student in each ear. This was done with a GSI 38 tympanometer. A probe tip was inserted into the child's ear, which measured outer and middle ear function. Then OAEs were performed twice on each ear with each of the two devices, for four total trials with each child. Each child was instructed to sit still and quiet during the duration of the testing. Pure tone audiometry was performed for each ear for every child. The child was instructed to raise his or her hand when they heard a tone through supra aural headphones. If the child didn't understand the task, or was unable to appropriately respond by raising their hand, they were instructed to drop a toy into a bucket when they heard a tone.

The entire procedure for each child took between 15-20 minutes. Each child was offered a break after each assessment. Test results were recorded on one sheet of paper to be kept by the tester, and another sheet of paper to be sent home with the child. Parents were informed of the screening results. The results that were sent home to the parents stated either that their child passed all portions of the screening, and no further recommendation was made, or that their child did not pass. In the case that the child did not pass, a recommendation was made to either consult with a doctor about their child's middle or outer ear, or to schedule a complete hearing evaluation by a licensed audiologist.

## Data analysis

Four sets of RMANOVA were conducted for the following DPOAE measures captured by the two devices: (1) average amplitude, (2) test-retest differences for average amplitude, (3) average noise floor amplitude, and (4) average SNR. Main effects for device and frequency were described and analyzed. Data for the right ear was only considered, as there were so technical issues with the data in our previous study in adults for left ear EROSCAN. Also given the small data set and subsequent lower statistical power a smaller number of analyses seemed more parsimonious for just using right ear data only.

# Results

## Average Amplitude

The results for average amplitude revealed significant differences for frequency. Although average amplitudes were higher for EROSCAN (Mean = 2.59, SD = 4.67) than for AuDx (Mean =1.49, SD = 7.72), these differences were not statistically significant [$F(1, 7) = 5.14$, $p = .058$]. Amplitudes were higher in the lower frequencies (Means = 7.59 and 2.44 dB SPL), while amplitudes decreased at each increasing frequency (Means = -2.31 and -4.38 dB SPL at 5000 Hz for EROSCAN and AUDx) for both devices (Figure 1 and Table 2). However, this was also not statistically significant ($p > .05$). Significant interactions for Device*Frequency were also not found ($p > .05$).

## Average SNR

SNRs were more positive for EROSCAN (Mean = 19.36 dB SPL, SD =5.63) than for AuDx (Mean = 14.00, SD =7.83) collapsed across all frequencies. This was statistically significant [$F(1, 7) = 8.55$, $p < .05$]. There was a greater difference between the two devices at the

lower frequencies. Although the results were not statistically significant for frequency [F (3, 21) =1.17, p>.05]. The results and statistical analyses for average SNR are displayed in Figure 4 and Table 2.

**Frequency*Device.** There was not a statistically significant interaction effect (p>.05). There were some qualitative differences between devices that were more pronounced at 2000 and 3000 Hz, with EROSCAN having more favorable SNRs (19.25 dB SPL, SD =7.04 dB SPL versus 11.25 dB SPL, SD =7.23 dB SPL at 2000 Hz) than AuDx. The average SNR for EROSCAN was highest at 3000 Hz (Mean=21.81, SD =6.50). The average SNR for AuDx was highest at 4000 Hz (Mean=15.88, SD = 7.83). Average SNR for EROSCAN was lowest at 5000 Hz (Mean=17.31). Average SNR for AuDx was lowest at 2000 Hz (11.25).

**Test-retest Amplitude**

The results and statistical analyses of test-retest for amplitude are described below and displayed in Figure 2 and Table 2. Test-retest differences were commonly greater for EROSCAN than AuDx, although these were not statistically significant for device [F (1, 7) =0.04, p>.05] or frequency [F (3, 21) =0.33, p>.05]. These ranged from 5.88 to 9.63 dB SPL compared to 6.00 to 8.38 dB SPL, respectively. Test-retest differences were greater for AuDx at the mid-frequencies 3000-4000 Hz (6.38 -8.38 dB SPL). The greatest differences between devices was at the highest frequency (AuDx Mean=6.00 dB SPL, SD =7.87 dB SPL; EROSCAN Mean=9.63 dB SPL, SD =10.50 dB SPL).

**Frequency*Device.** There was no significant interaction effect. Although, AuDx had a higher average than EROSCAN at 4000 Hz (AuDx Mean=8.37 dB SPL; EROSCAN Mean=6.6

dB SPL) while EROSCAN had a higher average than AuDx at 5000 Hz (EROSCAN Mean=9.63 dB SPL; AuDx Mean=6.00 dB SPL).

**Noise floor**

The results and statistical analyses for noise floor amplitude are described below and displayed in Figure 3 and Table 2. EROSCAN had lower noise floor amplitudes across all frequencies (Mean=-16.82 dB SPL, SD=2.21 dB SPL and Mean=-15.49 dB SPL, SD=2.85 dB SPL respectively). This was statistically significant device [$F(1, 7) = 5.88$, $p < .05$]. Noise floor amplitudes were most similar between the two devices at the highest frequency (EROSCAN Mean=-19.56 dB SPL, SD=0.90 dB SPL and AuDx Mean=-19.31 dB SPL, SD=1.19 dB SPL). Both devices had higher noise floor amplitudes at the lower frequencies NF was statistically significant for frequency [$F(3, 21) = 38.38$, $p < .001$].

**Frequency*Device.** Noise Floor amplitudes were most different between the two devices at the lower frequencies, although this was not statistically significant . Average noise floor amplitudes were highest at the low frequencies both for EROSCAN (2000 Hz Mean= -11.62 dB SPL) and AuDx (Mean at 2000 Hz=-8.81 dB SPL) (2000 Hz Mean=-19.56 dB SPL). They were more similar in the higher frequencies 4000-5000 Hz.

## Discussion

Although distortion-product amplitude (AMP) was not statistically significant between the two devices, AMP tended to be higher for EROSCAN. Average AMP was greater for EROSCAN across all frequencies, and the two devices had greater AMP in the lower frequencies compared to the higher frequencies. The results from a previous study with adults differ

comparatively. In that study, AuDx showed greater AMP across all frequencies. However, a similarity between the two studies was that both devices had the greatest AMP at 2000 Hz and the NF was lower for EROSCAN, especially at 2000 and 3000 Hz.

SNRs were significantly greater for EROSCAN across all frequencies in preschoolers. In the adult study, SNRs were not statistically significant between devices. SNRs between the two devices for preschoolers were most similar in the higher frequencies. Conversely, in the study with adults, SNRs were similar between the two devices at the lower frequencies, while AuDx showed better SNRs at the higher frequencies. SNRs for preschoolers for EROSCAN were better in part, due to greater AMP. This likely relates to the smaller ear canal volume in preschools compared to adults. Perhaps researchers achieved deeper probe-tip insertion with EROSCAN (rubber probe tip) compared to AUDx. EROSCAN has a larger number of probe-tip sizes compared to AUDx and may have created the opportunity for a deeper insertion of the probe. In both studies, NF was significantly lower for EROSCAN than AuDx, presumably resulting from its application of digital noise reduction. Digital noise reduction likely reduced noise floor amplitudes and thus led to improved SNRs for EROSCAN.

This finding is notable especially with the preschool-age population since hearing screenings are typically performed in a school setting. A limitation of hearing screenings is the possible interference of ambient noise, which is typically low frequency. Digital noise reduction with EROSCAN may be the more appropriate device to use since it yields lower noise floors and greater SNRs. This is a major consideration between the two devices. Although the two devices have similar pass-fail criteria for SNR and amplitude, performance varies between the two devices.

Test-retest was poor for both devices, especially compared to the small values seen for the adults. The average TRT for adults with AuDx was 1.5 and 2.2 with EROSCAN. The average TRT for preschoolers with AuDx was 6.7 and 7.3 with EROSCAN. TRT differences were significantly greater with EROSCAN at the higher frequencies with adults. Unlike for adults, AuDx was not better than EROSCAN with preschoolers, with the exception of 5000 Hz where values tended to be larger for EROSCAN. Small TRT differences with adults was attributed to consistent probe tube placement with the foam tip. This theory is not supported by the data from the current study as TRT differences were not generally better with AuDx. The discrepancy between TRT differences may be attributed to the fact that multiple people administered the testing and therefore probe tube placement may have been inconsistent. This is another major consideration in terms of hearing screenings. Because hearing screenings are often times administered by individuals with limited training, a device that yields low TRT differences may be desirable.

The results for both studies are inconsistent with conclusions by Parthasarathy & Klosterman (2001) compared DPOAE amplitude obtained with four devices, including three screeners (AuDx, EROSCAN and the Audioscreener) for adult participants. They found no overall significant differences between devices. Others (see Hornsby et al. 1996) have emphasized that probe-tip assemblies may be significant factors for the higher test frequencies, which are susceptible to standing waves. Although results here consistently had EROSCAN having greater amplitude across all frequencies, which does not necessarily suggest a high frequency standing wave problem, but rather deeper probe insertion for EROSCAN, possibly a result of the availability of a larger selection of probe-tip sizes, resulting in greater response amplitude.

## Conclusions

DP amplitudes were not significantly different between the two screning devices. Amplitudes were greater for EROSCAN, whereas AMPs were greater with AuDx in the adult study. EROSCAN yielded lower noise floors in both studies, likely because of the digital noise reduction. Both devices had very poor TRT compared to the adult study, which may not be surprising as testing for the preschoolers was done in a less controlled screening setting located in a classroom instead of a clinic sound booth. The application of digital noise reduction may be beneficial when screening in schools because ambient low frequency noise is often present. Poor TRT may be due to poor or inconsistent probe tube placement. A key consideration between the two devices is the differences in probe tip. Probe tip insertion depth and ear canal volume are major variables between the current study and the previous adult study.

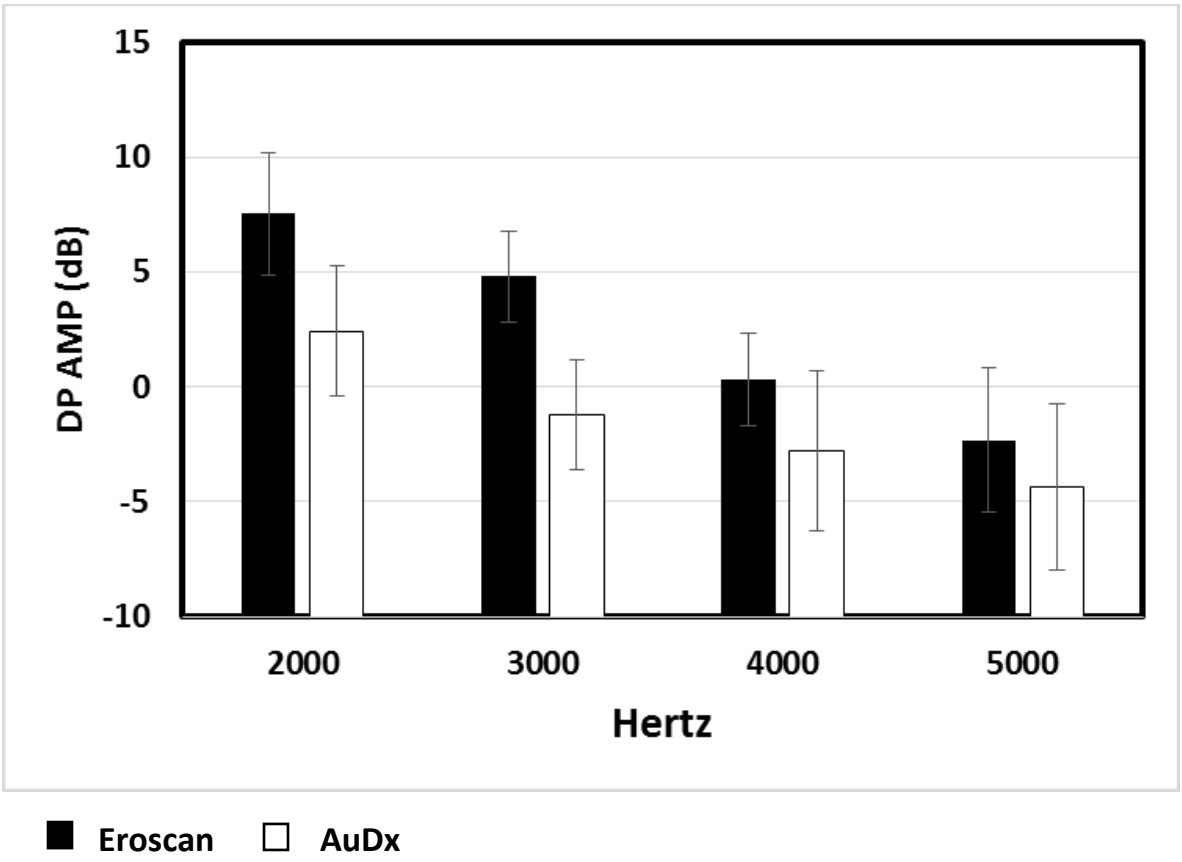


Figure 1. Mean DPOAE amplitude for the right ear.

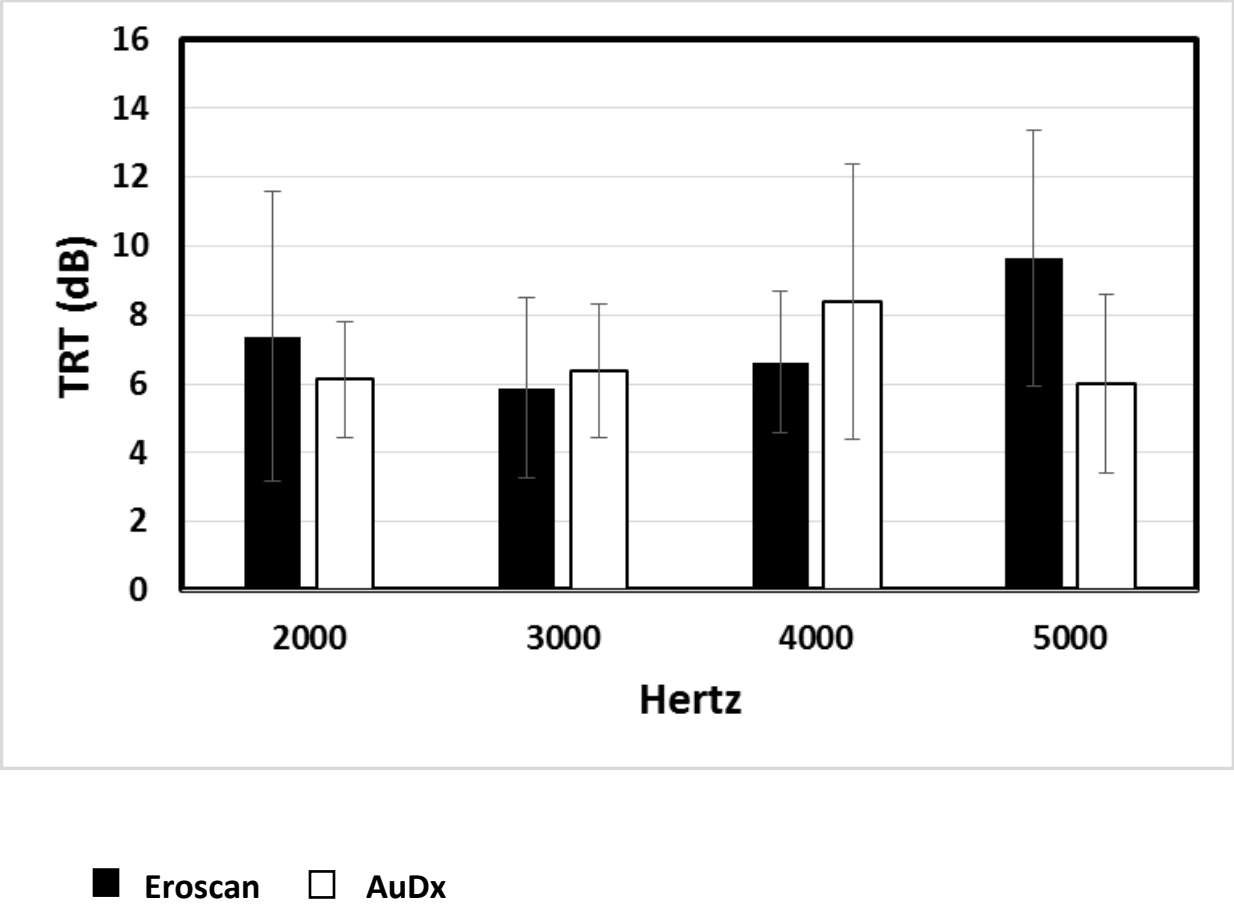


Figure 2. Right ear test-retest differences for DPOAE amplitude (dB SPL) for both devices.

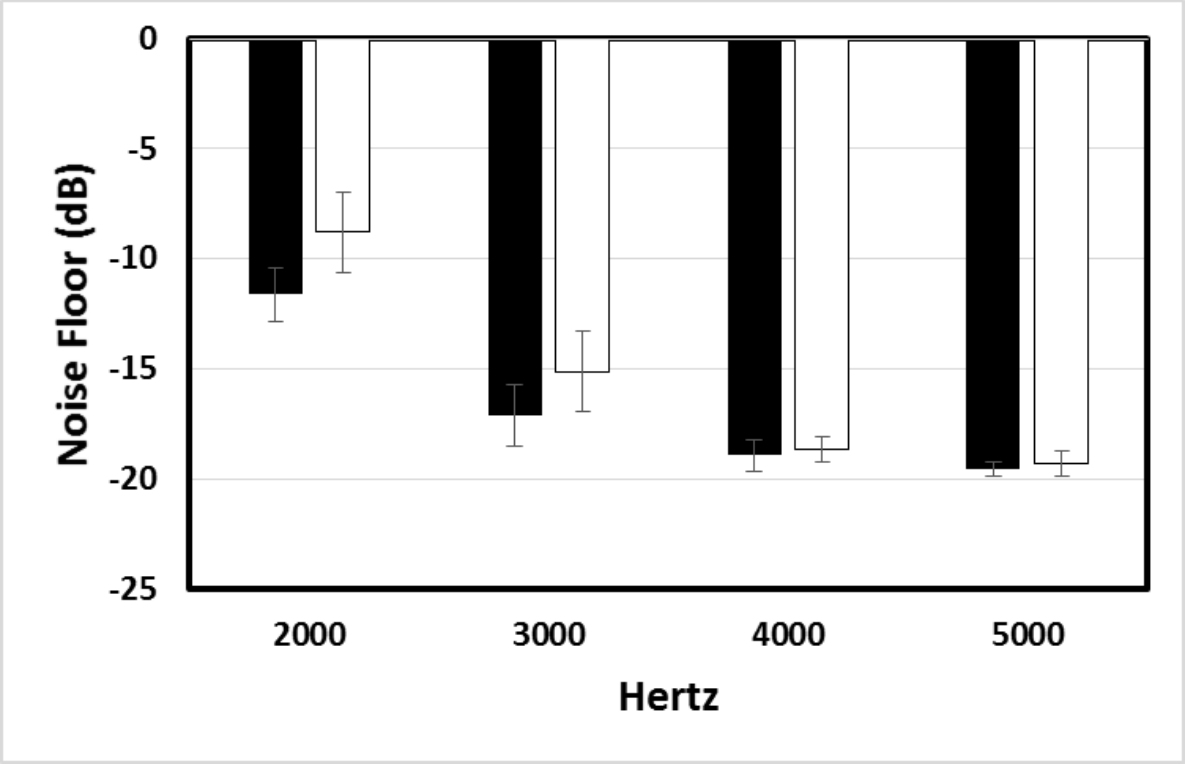


Figure 3. Mean noise floor amplitude (dB SPL) for the right ear for both devices.

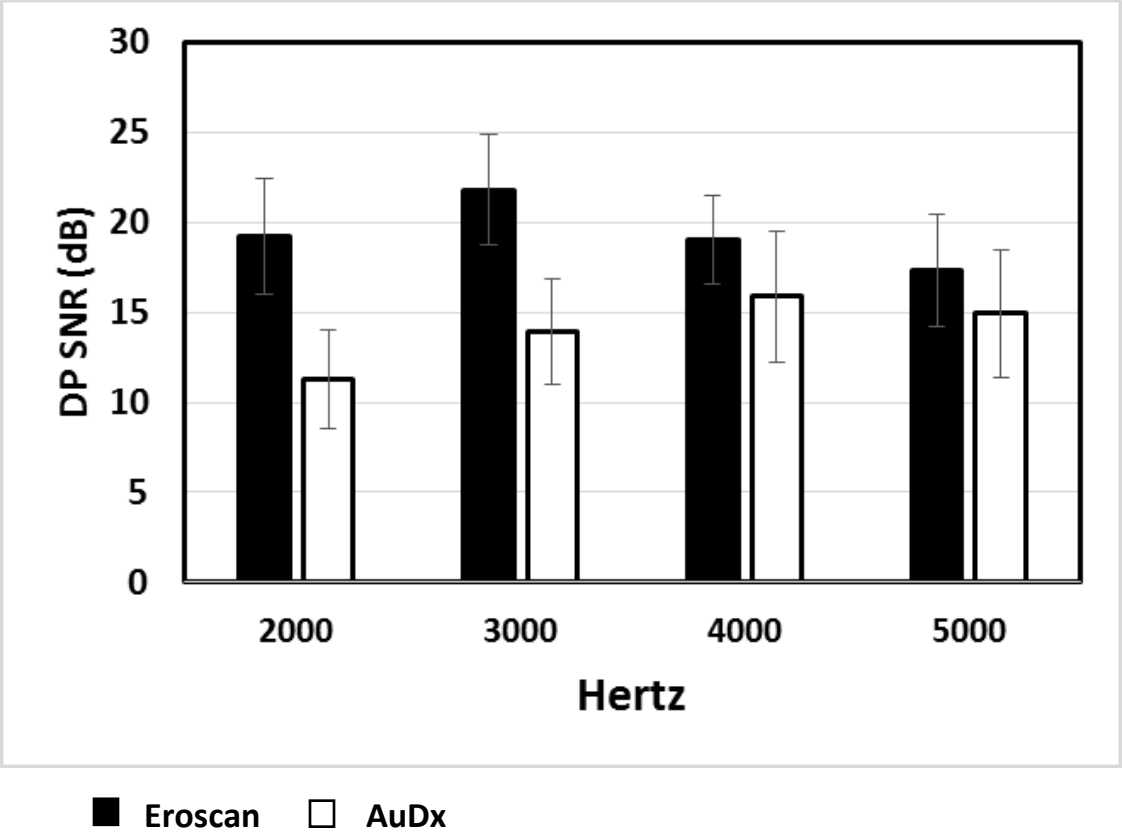


Figure 4. Mean DPOAE SNR (dB) for the right ear for both devices.

Table 1. RMANOVA statistics for AMP, SNR, NF and TRT

| Measure | df | *F* | *p* | Partial $\dot{\eta}^2$ |
|---|---|---|---|---|
| SNR | | | | |
| Device | (1,7) | 8.55 | **<.05** | .55 |
| Frequency | (3,21) | 1.17 | >.05 | .14 |
| Device * Frequency | (3,21) | 2.07 | >.05 | .23 |
| AMP | | | | |
| Device | (1,7) | 5.14 | .058 | .42 |
| Frequency | (3,21) | 1.17 | >.05 | .55 |
| Device * Frequency | (3,21) | 0.86 | >.05 | .11 |
| NF | | | | |
| Device | (1,7) | 5.88 | **<.05** | .46 |
| Frequency | (3,21) | 38.38 | **<.001** | .85 |
| Device * Frequency | (3,21) | 1.83 | >.05 | .21 |
| TRT | | | | |
| Device | (1,7) | 0.04 | >.05 | .01 |
| Frequency | (3,21) | 0.33 | >.05 | .05 |
| Device * Frequency | (3,21) | 0.52 | >.05 | .07 |

Table 2. Descriptive values for SNR, DP AMP, Noise Floor, and Test-retest for the right ear for both devices.

| | *EROSCAN* | | | *AUDx* | | |
|---|---|---|---|---|---|---|
| Measure | *N* | *Mean* | *SD* | *N* | *Mean* | *SD* |
| SNR | | | | | | |
| 2000 | 8 | 19.25 | 7.04 | 8 | 11.25 | 7.23 |
| 3000 | 8 | 21.81 | 6.50 | 8 | 13.94 | 7.25 |
| 4000 | 8 | 19.06 | 4.12 | 8 | 15.88 | 7.83 |
| 5000 | 8 | 17.31 | 4.86 | 8 | 14.94 | 9.01 |
| **AVE** | **8** | **19.36** | **5.63** | **8** | **14.00** | **7.83** |
| AMP | | | | | | |
| 2000 | 8 | 7.56 | 5.34 | 8 | 2.44 | 7.50 |
| 3000 | 8 | 4.81 | 4.32 | 8 | -1.19 | 5.64 |
| 4000 | 8 | 0.31 | 3.95 | 8 | -2.81 | 7.26 |
| 5000 | 8 | -2.31 | 5.06 | 8 | -4.38 | 9.26 |
| **AVE** | **8** | **2.59** | **4.67** | **8** | **1.49** | **7.42** |
| NF | | | | | | |
| 2000 | 8 | -11.63 | 2.71 | 8 | -8.81 | 4.85 |
| 3000 | 8 | -17.13 | 3.56 | 8 | -15.13 | 3.90 |
| 4000 | 8 | -18.94 | 1.66 | 8 | -18.70 | 1.46 |
| 5000 | 8 | -19.56 | 0.90 | 8 | -19.31 | 1.19 |
| **AVE** | **8** | **-16.82** | **2.21** | **8** | **-15.49** | **2.85** |
| TRT | | | | | | |
| 2000 | 8 | 7.38 | 11.87 | 8 | 6.13 | 4.79 |
| 3000 | 8 | 5.88 | 7.43 | 8 | 6.38 | 5.53 |
| 4000 | 8 | 6.63 | 5.78 | 8 | 8.38 | 11.29 |
| 5000 | 8 | 9.63 | 10.50 | 8 | 6.00 | 7.87 |
| **AVE** | **8** | **7.38** | **8.90** | **8** | **6.72** | **7.37** |

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